WATER EFFICIENT TECHNOLOGIES FOR IRRIGATED COMMANDS

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Water, a unique resource on the planet earth, is essential for sustaining all forms of life, food production, economic development, and for general well being of the life on the planet. The importance of water could be gauged from the fact that while looking for life on other planets, presence of water on the planet is first examined as an indicator of the presence of life on the planet. Civilizations have been developed along the rivers. Yet, it would not be an exaggeration of fact that civilizations doomed not because the water was not available but because the water was misutilized resulting in unsustainable use of the resources.

India's share in global resources

Resources	Per cent
Human Resource	16.0%
Land Resource	2.45%
Water Resource	4.00%
Livestock Resource	15.0%

India's natural and water resources

Particulars	Area and per cent
Geographical area	328.7 m.ha
Net Irrigated Area	54.0 m.ha
Total area under irrigation	80 m ha
Ground water	53.0%
Surface water	40.5%
Potential Irrigable	113.5 m.ha
Net cultivated area	139.7 m.ha
Net Rainfed area	85.7 m.ha
Gross irrigated area	79.0 m.ha
Ultimate irrigation potential	139.9 m ha
Irrigation potential of Karnataka	311.390 in thousand hectre

Source: Ministy of Water Resources, 2008-09

Irrigated area under different crops

Crop	Area m ha	Per cent covered
Rice	24.57	56.7

Wheat	25.64	90.2
Maize	1.72	21.5
Total cereals	54.27	53.2
Total pulses	3.66	15.4
Total food grains	57.93	46.4
Sugarcane	4.83	92
Oil seeds	8.25	28.6
Cotton	3.2	35

SURFACE WATER RESOURCES OF INDIA

From the point of view of surface water resources, India has been divided into 20 river basins. These comprise of 12 major basins each having a catchments area exceeding 20,000 sq km and 8 composite river basins combining suitably together all the other remaining medium and small river systems. The total water potential of these basins is estimated at 187.9 million ha million. A break up of this resource reveals that 105 million ha m is the runoff from rainfall that flows into rivers and streams including reservoir and tanks. Additional water is received from snow melt (10 million ha m), flow from outside India (20 million ha m), from groundwater (37 million ha m) and from irrigated areas (11 million ha m) making a total of about 183 million ha m. The largest potential of water is available in Ganga/ Brahmaputra/Barak and others making a total of 117 million ha m followed by Godavari and by west flowing rivers from Tapi to Tadri each having an average annual potential of more than 10 million ha m. Due to extreme variability in precipitation, which disallows assured storage of all the water, due to non-availability of storage space in hills and plains, evaporation losses and water going to the sea and outside India, it is anticipated that utilizable surface water resources would be 69 million ha m which will be utilized by the year 2025. It is assessed that on full development, 76 million ha area would be irrigated through surface water resources.

GROUNDWATER RESOURCES OF INDIA

Groundwater is also an important source of water that accounts for about 80% of domestic water requirement and more than 45% of the total irrigation in the country. Replenishable groundwater resource is mostly derived from the precipitation. Out of 400 million ha m, 215 million ha m of rain water percolates into the ground out of which only 50 million ha m joins the groundwater or is available for exploitation. The state wise groundwater potential as recently estimated by Central Ground Water Board (now Authority) is 43.2 million ha m. Basin wise estimates reveal that Ganga basin has the maximum groundwater potential and account for more than 38% of the total groundwater potential. It is followed by Brahmani and Baitarni at 5.9 million ha m. After deducting the provision for domestic and industrial purposes, the potential available for irrigation is 36.03 million ha m. The utilizable groundwater for irrigation is thus assessed at 32.47 million ha m. It is likely to increase to 35 million ha m in 2025.

PROBLEMS OF WATER RESOURCES IN INDIA

1. Spatial and temporal distribution

On an average over space and time, average annual rainfall over the Indian sub-continent has been estimated at 1200 mm. The highest rainfall of about 11,690 mm is recorded at Mousinram near Cherrapunji in Meghalaya in the northeast (Bose and Saxena, 2001). In this region rainfall as much as 1040 mm is recorded in a day. At the other extreme is places like Jaisalmer, in the west, which receive barely an annual average rainfall of 150 mm. On this basis, the annual precipitation including snowfall is estimated at 400 million ha m (4000 km3). Distribution of this resource with respect to different rainfall zones reveal that more than 50% of the resource is generated in the zone with rainfall ranging from 1000-2500 mm. The area receiving less than 1000 mm of rainfall constituting about 48% of the geographical area contributes only 24.6% of the water resource. About 300 million ha m of this resource is generated during June to September while another 100 million ha m is during the rest of the year.

2. CONFLICTING OBJECTIVES OF WATER RESOURCES DEVELOPMENT

Major and medium projects are multipurpose projects with hydropower generation, flood control and irrigation. For example, irrigation requirement could be quite different over the seasons/years while hydropower generation may require steady release of water to meet any eventuality. Similarly storage for irrigation and hydropower may overweigh concerns for the flood control. Therefore, operational aspects of multi-purpose projects need to be optimized to meet most objectives

3. INCREASING SECTORAL COMPETITION BETWEEN SECTORS

Increasing population, change in eating habits, life style changes and increasing emphasis on travel/tourism and environment, the demand scenario of water is expected to change drastically. Agriculture, which is currently consuming 83% of the developed water resource, would be the looser and would have to sacrifice fresh water for the interests of other sectors of economy. Although, overall quantity of water allocated to agriculture would increase yet it would be less than the demand. Therefore, agriculture needs to look at other sources particularly the so-called wastewaters released after first use by other sectors. Researches on the use of such waters have already begun with right earnest.

4. POLLUTION OF SURFACE AND GROUNDWATER RESOURCES

We are all witness to extreme pollution levels of surface water bodies and more so of the rivers, which turn into drains during non-monsoon season, as effluents from large number of municipal and industrial establishments are being discharged untreated into the rivers. The groundwater pollution is even more serious which goes unnoticed and remains hidden from the public view. Non-point source (agriculture use of excessive fertilizers, insecticides and pesticides) and point sources (disposal of industrial and domestic sewage) have resulted in increase contaminant concentrations exceeding the limits prescribed by World Health Organization (WHO).

5. IRRIGATION AND CROP PRODUCTIVITY

Rainfall is the most significant climate factor that affects the crop growth and production from the rainfed areas in the country. A good example is the interaction between annual food grain production in India and the summer monsoon rainfall. The annual rainfall in the rain fed region is quite erratic with large spatial and temporal variations. The coefficient of variation increases with decreasing rainfall. While it is about 20% in dry sub-humid region, it is as high as 61% in the arid rainfed region. Besides water, other bio-physical and socio-economic constraints limit the productivity of crops and livestock. Progress has been quite slow in rain fed agriculture, which constitutes bulk of our agricultural land. The productivity of rain fed agriculture is less than half of the productivity of irrigated lands It may be seen that irrigation can lead to substantial improvements in the productivity of rain fed crops. A major concern, however, stems from the fact that even the productivity of irrigated agriculture is not as high as anticipated in the project proposals or as spectacular as in other countries. There is no national level assessment of the overall irrigation efficiencies. The irrigation efficiency in surface irrigation systems might be in the range of 35-40% while it could be 65-70% for groundwater. Overall low productivity of Indian irrigated agriculture could be attributed to inefficiencies of the system. Lag in utilization of irrigation potential is also a cause of concern. The irrigation potential utilized is around 90 % of the developed irrigation potential. It has locked in huge investment made in developing the irrigation potential. A modest estimate would reveal locking up of Rs. 12500 billion due to nonutilization of the potential alone.

6. PARADOX OF RISING AND FALLING WATER TABLE

Most irrigation projects in India are operating at low efficiencies. Clearly, 60-65% of the irrigation water is lost either during conveyance or in the fields. This has led to rising water table in irrigation commands, particularly in areas underlain with poor quality ground waters. This has also given rise to problems of water logging and soil salinization since these are considered to be twins. It is estimated that around 6.73 million ha of agriculturally productive lands have turned barren because of these twin problems. Large areas might be producing below the potential productivity. The estimate for such areas has not been made so far. Because of the inadequacy and unreliability of canal waters, farmers have gone for intensive irrigation through the development of groundwater. Over-exploitation of groundwater is causing water table to decline by 0.2-1.0 m per annum.

7. WATER-THE CAUSE OF THE CONFLICTS

War or no war, yet danger of large conflicts arising over water can not be ruled out., India has several such conflict zones with Pakistan, Bangladesh and Nepal. World war over water foreseen by policy planners might or might not occur but fierce fight for water within states in India has already begun with no end in sight. Conflicts between Tamil Nadu-Karnatka-Andhra Pradesh and Punjab-Haryana-Rajasthan are too well known.

Effect of saline and alkaline water

- Sodic water adversely affects soil physical properties
- The increased exchangeable sodium percentages (ESP) as result from their long-term use affects soil structure due to swelling and dispersion of clay participles. Fine textured soils remain dispersed and puddle when wet and hard when dry
- A thin curst is often formed at the soil surface, which acts as a barrier to water infiltration and seedling emergence
- Increase in soil pH reduces the availability of a number of plant nutrients such as nitrogen, zinc, iron, etc.
- Irrigation with sodic water also results in decreased availability of calcium and magnesium and toxicity of sodium
- In most cases, the yield of crops is a adversely affected by a combination of these factors

WATER RESOURCES- CHALLENGES AHEAD

When one looks at the statistics that is being fed through the media, one becomes quite skeptical to the future scenario. Doubts have been raised on the socio-economic development, sustainability of irrigated agriculture and environmental quality. But let us face the facts. Water has been as scarce in the past as it was when our population was a fraction of what we are today. Our forefathers were equally worried about the scarcity and pollution of surface water bodies. Yet we could survive so far. There are still many opportunities to tap our water resources. Let us look at some of these opportunities so that we can make a better choice in exploiting these resources. It is estimated that a 10% improvement in agriculture sector could compensate the 40% increased demand of domestic and industrial sectors. Some of the issues are discussed in following sections.

IRRIGATION IMPROVEMENT

Suggestion on modernization of existing irrigation systems with better operation and maintenance, rationalization of water rates, techniques for equitable water distribution, night irrigation, dynamic regulation through decision support system, computer use, information technology and advanced methods of communication have emerged at various forums. Inadequacy and uncertainty is being tackled through inter-basin transfer of water. It is slowly becoming a reality. It has been estimated that in due course of time inter-basin transfer of water would add to 35 million ha of irrigated lands. Participatory Irrigation Management (PIM) could play a very effective role in irrigation management. Many people think it to be the panacea for all the ills that plague the irrigation system. Such a overemphasis on this issue has already burdened the concept of PIM and voices are now heard to go for privatization of the irrigation system in participatory mode.

REUSE OF DRAINAGE WATER

Not long back drainage waters were treated as wastewaters. Analysis of water samples from surface drains showed that water in these drains during monsoon season is of good quality and it can be used in agriculture without affecting the land resource or the crop yields. Fortunately for the nation, farmers are quite conscious of this fact and this source is being exploited to the hilt. It is very encouraging scene to see the farmers pumping water from the drains, borrow pits and depressions to irrigate their fields. Water so pumped is being transported for more than a kilometer.

EXPLOITATION OF SALINE/SODIC WATERS

Conjunctive use of saline ground water with good water will meet the requirement partially under scarcity conditions

MULTIPLE USE OF WATER

Multiple use of water within agriculture sector should also be implemented to enhance water productivity. Aquaculture with agriculture could be one major activity, where value added water from aquaculture would be used to irrigate crops.

SEPARATION OF GREY/BLACK WATERS

Grey water is the water released from washbasins, kitchens and bathrooms etc. This water is relatively of good quality and could be used to irrigate lawns/kitchen gardens. On the other hand sewage water is black water. The quantity of black water is quite large because currently grey and dark waters are being mixed up creating problems of disposal. In many countries it is now mandatory to separate grey and black waters. The day is not far off when we would need to adopt such regulations to reutilize grey waters to minimize the disposal related problems.

TECHNOLOGY UPGRADATION IN IRRIGATED AGRICULTURE

Irrigation plays a vital role in Indian agriculture. The impact of irrigated agriculture on water Irrigation plays a vital role in Indian agriculture. The impact of irrigated agriculture on water resources is significant since it uses 85% of the total water resources in the country with net irrigated area of 54 million ha. The limits to the availability of water and land for irrigated agriculture necessitate the careful use of water resources for achieving higher water use efficiency. The lower the water resource input requirement per unit of crop yield produced, the higher the efficiency. Further the water use efficiency is closely related to water requirement. By achieving higher water use efficiency and efficient utilization of irrigation water the potential irrigation area can be increased to more than 100 million ha. In India 70 per cent irrigated area being covered by rice and wheat and 92 per cent of sugarcane crop is irrigated followed by rice (56.7%), oil seeds (28.6%) and maize (21.5%) crops.

The growing water scarcity and misuse of available water resources are now a days major threats to sustainable agricultural development. The studies carried out at University of Agricultural Sciences, Dharwad through farmers participatory on station and on farm research programmes showned higher water use efficiency, saving in irrigation water and higher yield in the canal irrigation commands and tank irrigation commands.

Any practice that promotes plant growth and the more efficient use of sunlight in photosynthesis without causing a corresponding increase in ET will increase WUE.

Crop	**Water requirement (mm)**	**WUE (kg/ha-mm)**
Rice	2000	3.0
Sorghum	500	9.0
Pearl millet	500	8.0
Maize	625	8.0
Wheat	280	12.6
Groundnut	506	9.2
Finger millet	310	13.4

STRATEGIES TO ENHANCE WATER USE EFFICIENCY

Drought resistance for a crop can be affected by many agronomic measures. Some measures are critical for improving WUE, and can be achieved with relatively simple changes to production practices.

1. Crops /cropping systems adoption: Most suitable crops/cropping systems have to be adopted, based on the water supply situations in the command areas. In Malaprabha Command Area of Karnataka, for all water supply situations, ie., water supply from July-August to November, December, January and February, maize-chickpea and maize-wheat crop sequence were found more suitable sequence for vertisols. Presently 2.5 lakh ha area is under this system in Malaprabha and Gharaprabha commands. Net income of 70 to 75 thousand can be obtained with higher B:C ratio(3.50). Irrigated dry chilli with drip irrigation with Jayadhar cotton as relay crop and onion with sprinkler irrigation are other profitable commercial cropping systems. Among vegetables bhendi and french been cropping system were found most remunerative with irrigation at 12-15 days interval in vertisols. Introduction of horticulture crops guava and pomegranate under drip irrigation with irrigation at 11,17 and 22 litre /plant/day once in two days during *kharif*, *rabi* and summer seasons are becoming popular. The 8 l / hour drippers for irrigation at operating pressure of 0.5 kg/sq.cm was found optimum.

2. Irrigation management

WUE can be improved with better systems for conveyance, allocation and distribution and water losses can be drastically reduced by using irrigation methods including drip irrigation systems that allow water to be delivered precisely when and where it is needed.

In Malaprabha and Ghataprabha command areas, alternatively alternate furrow irrigation in hybrid maize, hybrid cotton and chickpea saved irrigation water by 25-27%. Border strip method of irrigation in wheat and chickpea with cut off irrigation water at 80% of the length of the border strip saves irrigation water by 15-20%. Drip irrigation to maize-chickpea sequence is most remunerative with saving in irrigation water upto 40-50 per cent. Drip irrigation to chilli and hybrid cotton at 40% PE (1.8 l/plant) at every 3 days interval produced higher yield. Dryland fruit crop ber irrigated at 35-38 l/day/plant increased the yield and saved irrigation water by 35-40%. Similarly in closed spaced curry leaf (1 mx 1m), irrigation at 1.0 l/day/plant increased the yield and saved irrigation water by 55-57%. In onion irrigation through sprinkler with 30 mm depth once in eight days (0.8 IW/CPE) in vertisols with laterals and nozzles laid out at 12 m spacing with operating pressure of 3 kg /sq cm was found optimum.

3. Soil Enhancement

In addition to the inherent efficiencies of different irrigation methods, a number of additional soil enhancement approaches can be considered to improve the efficiency of irrigation practices. Water savings can be achieved through residue management and conservation tillage. These practices improve the ability of the soil to hold moisture, reduces water runoff from the field and reduce surface evaporation. Application of organic manures enhanced the available soil moisture in different crops (NPOF, 2009-10). Application of micronutrients, iron sulphate and zinc sulphate @ 25 kg/ha each mixed with 50 kg vermicompost to hybrid maize, cotton, chilli, bhendi etc. in Malaprabha command has increased the yield by 15-28 % (AICRPWM, 2008-09). In situ green manuring of sunnhemp with maize at 1:1 row ratio at 30 cm row spacing and incorporating it at 40-45 days after sowing increased the crop productivity and soil fertility. Application of recommended organic manures and bio-fertilizers along with chemical fertilizer enhanced the crop productivity and maintained the soil health under irrigated conditions. Application of silicon improved the yield and water use efficiency in maize under water stress conditions by reducing leaf transpiration and water flow rate in xylem vessels (Gao *et al*., 2004).

4. Genetic factors

Crop growth and yield is a result of interaction between their genetic constitution and environmental conditions in which they grow. High yielding varieties, hybrids due to their dwarf plant type, erect leaves and high specific leaf weight are responsive to water and fertilizer and high harvest index exhibit higher WUE. Drought tolerance of plant is determined by a large number of physiological and morphological triats.

IMPROVING CROP WATER USE EFFICIENCY USING CARBON ISOTOPE DISCRIMINATION

The method based on carbon-13 discrimination (delta) in plant tissues has a potentially important role in the selection and breeding of some crop species for increased water use efficiency in some specific environments. Under various water-limited environments, low delta in the plants, indicating low carbon isotope discrimination has been generally associated with high transpiration efficiency (TE). In contrast, for well-watered environments many positive genotypic correlations have been reported between delta and grain yield indicating potential value in selecting for greater delta in these environments. Few studies have been reported on the impact of selection for delta on adaptation and grain yield in saline environments.

Water saving strategies in agriculture

- On farm land and water management technologies
- Land leveling
- Zero tillage
- Bed and furrow farming
- Precision farming,
- Improved surface irrigation techniques
- Land drainage
- Improved pressurized irrigation techniques
- Improved agronomic practices that would include time of sowing, crop varieties, cropping systems, conjunctive use and mulching
- Crop diversification
- Adopt Rainwater harvesting to enhance ground water storage
- Irrigation regime in rice crop including shallow submergence, irrigation scheduling at hair cracking and dry seeding or irrigations at critical stages in other crops
- Deficit irrigation particularly under high water table conditions
- Pricing and legal restrictions on water use
- Use of virtual water concept to control demand
- Waterlogged saline soil reclamation programmes

Strategies to increase the water resource

- Use of Fog and dew
- Green and Blue water Syndrome
- Watershed and flood management
- Increase in storage capacity
- Interbasin transfer of water
- Minimization of waste
- Reuse or use of non-conventional naturally occurring saline or domestic and industrial waste water and Desalination of sea water.

SRI AND AEROBIC RICE CULTIVATION TO SAVE THE IRRIGATION WATER

The system of rice intensification (SRI) is a new and evolving alternative to conventional methods of rice cultivation. In this method, rice seedlings are transplanted early (eight to 12 days old compared to 21 days in the conventional method). They are transplanted in un-puddled condition; the seedlings are widely spaced (up to 20, 25, 30 or even 50 cm apart). The fields are alternately kept wet and dry; they are not flooded until the panicle initiation stage (1-3 cm of water in the field during the reproductive phase). The field is drained 25 days before harvest and organic manure is used as much as possible. Mechanical weeding should start around 10 days after transplantation; at least two weeding are necessary, more are recommended. It is supposed to provide better growing conditions in the root zone, save inputs, improve soil health and optimise water use efficiency.

The looming global water crisis threatens the sustainability of irrigated rice, which is the Asia's biggest water user. Aerobic rice is a new concept of growing rice in non-puddled and non flooded aerobic soil. Aerobic rice is a water-saving rice production system in which potentially high yielding, fertilizer responsive adapted rice varieties are grown in fertile aerobic soils that are non-puddled and have no standing water. Supplementary irrigation, however, can be supplied in the same way as to any other upland cereal crop (Wang *et al*., 2002; Bouman *et al*., 2005). The yields that can be obtained here range from 4.5 to 6.5 t ha^{-1} (Wang *et al*., 2002). For the tropics, the aerobic rice system is still under development. But also here, high yields can be obtained; in transplanted aerobic rice, e.g. up to 6 t ha^{-1} (Bouman *et al*., 2005); but even though yields remained generally greater than 3 t ha^{-1}, gradual yield decline was observed under continuous cultivation.

USE OF ANTITRANSPIRANTS

Film-forming antitranspirants cause about a 50% reduction of transpiration and photosynthesis in all species. Effectiveness decayed slowly over 10-14 days. Effectiveness of the silicone antitranspirant was very short-lived. Water use efficiency was slightly improved following film-forming antitanspirant (Anderson, 1978).

The 'film type' of antitranspirants reduced transpiration only at a considerably higher concentration than the 'stomatal type' of antitranspirants. Of the 'stomatal type' of antitranspirants phenyl mercuric acetate (PMA) was the most effective substance. Under actively transpiring conditions a 250 ppm solution of PMA reduced transpiration by about 30 per cent (Nagarajah, 1977).

DRIP IRRIGATION

Water saving and improved water use efficiency are the two important advantages of drip method of irrigation. According to the experimental data from different research stations located in India, water saving due to drip method of irrigation varies from 12 to 84 percent over the conventional method of irrigation in vegetable crops. In fruit crops, water saving varies 45 to 81 percent. In sugarcane, which is a water-intensive crop, water saving is estimated to be over 65 percent due to drip method of irrigation.

The results of field level data pertaining to three crops namely sugarcane, banana and grapes are somewhat different from the experimental results. The pattern of water use for crops is totally different between the two methods of irrigation. The drip adopters have applied more number of irrigation per hectare when compared to the non-drip adopters in all the three crops considered for the analysis. However, hours required per irrigation to irrigate per hectare of sugarcane, grapes and banana are significantly less for the drip adopters as compared to the non-drip adopters.

Water consumption (in quantity) per hectare is much less under drip method of irrigation as compared to flood method of irrigation in all the three crops. Water saving in sugarcane due to drip method of irrigation is about 44 percent, while the same is estimated to be about 37 percent in grapes and 29 percent in the case of banana.

Additional area can also be brought under irrigation from the saving of water realised through the adoption of drip method of irrigation. The additional irrigated area possible from the saving of water is estimated to be 0.80 (1.98 acres) in sugarcane, 0.60 ha (1.48 acres) in grapes and 0.41 ha (1.01 acres) in banana.

Water use efficiency (i.e., water consumed to produce one unit of crop output) is also significantly higher in drip-irrigated crops when compared to the same crops cultivated under non-drip irrigated condition. Sugarcane cultivated under drip method of irrigation consumes only 1.28 horse power (HP) hours of water to produce one quintal of sugarcane as against 2.83 HP hours of water under flood method of irrigation, i.e., about 1.55 HP hours of additional water is consumed to produce one quintal of sugarcane under flood method of irrigation. Banana crop under DMI consumes only 11.60 HP hours of water to produce one quintal of output as against the use of 21.14 HP hours of water under non-drip irrigated condition. In grapes, each quintal of output involves the use of just 13.60 HP hours of water under DMI as compared to the use of 25.84 HP hours of water under non-drip irrigated condition s(Narayanamoorthy, 2005).